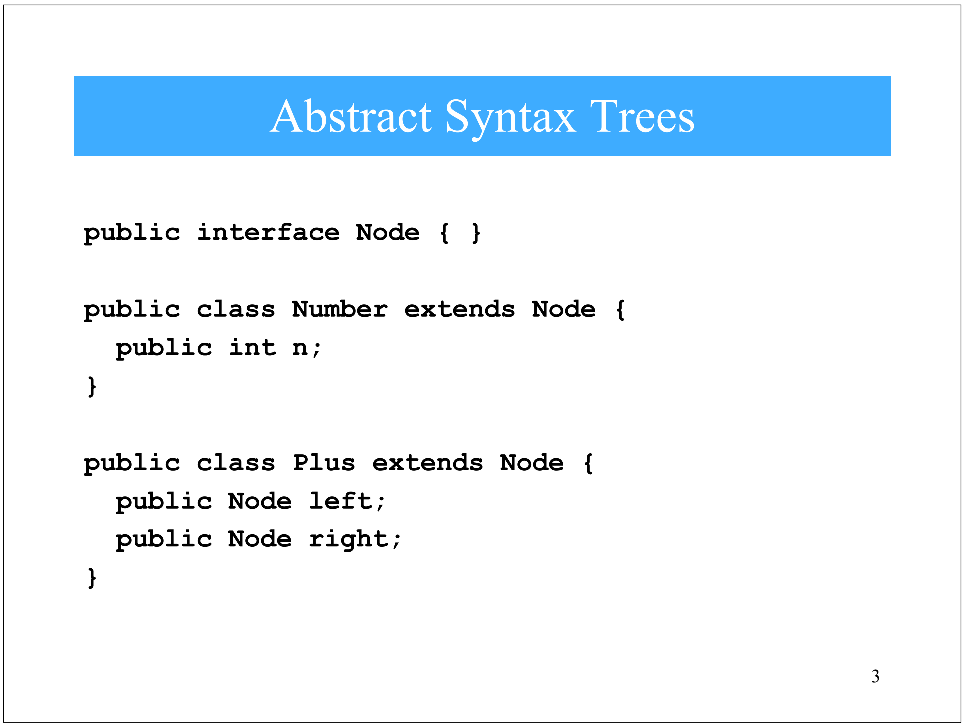
CMSC 433 – Programming Language Technologies and Paradigms
Spring 2006

Visitor Design Pattern

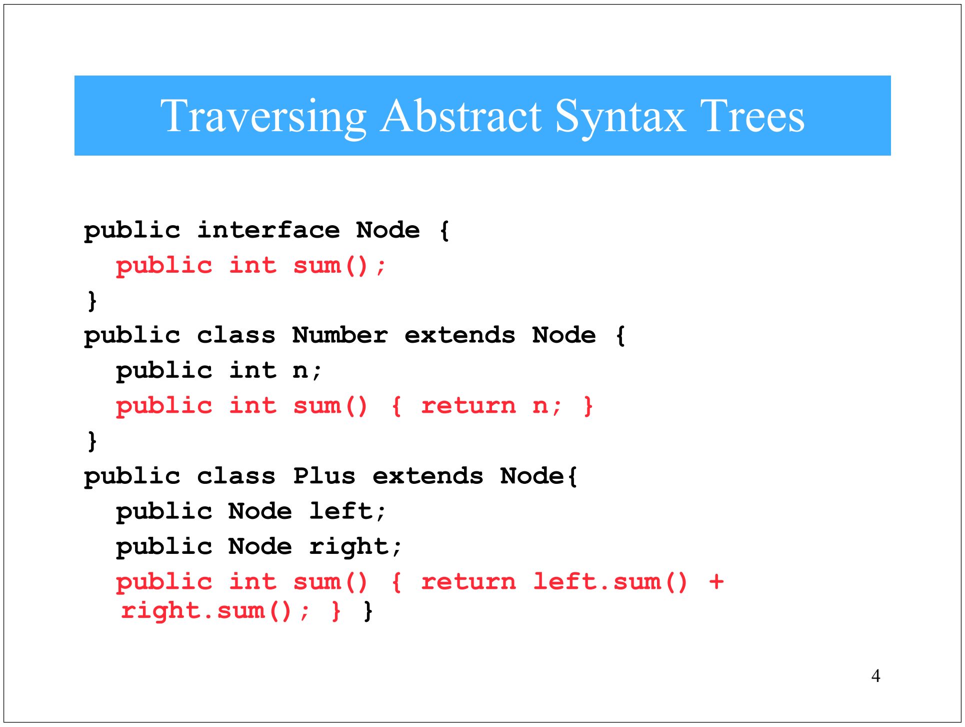
Visitor: Implementing Analyses

- Often want to implement multiple analyses on the same kind of object data
  - Book example: computing with Menus
  - Project example: Generating code for and analyzing an Abstract Syntax Tree (AST) in a compiler
- One solution: implement each analysis as a method in each object



Abstract Syntax Trees

```
public interface Node { }

public class Number extends Node {
  public int n;
}

public class Plus extends Node {
  public Node left;
  public Node right;
}
```

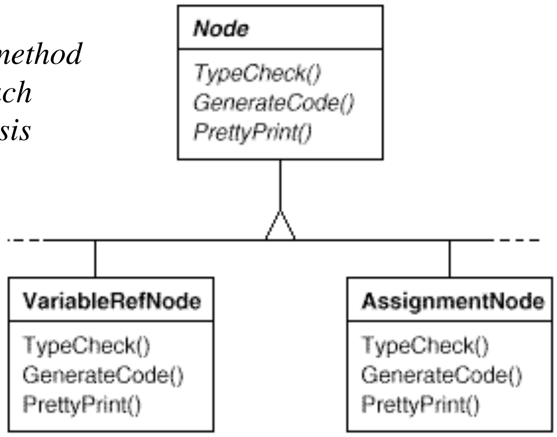


Traversing Abstract Syntax Trees

```
public interface Node {
  public int sum();
}
public class Number extends Node {
  public int n;
  public int sum() { return n; }
}
public class Plus extends Node{
  public Node left;
  public Node right;
  public int sum() { return left.sum() +
   right.sum(); } }
```

Naïve approach (not a visitor)

One method for each analysis



Tradeoffs with this Approach

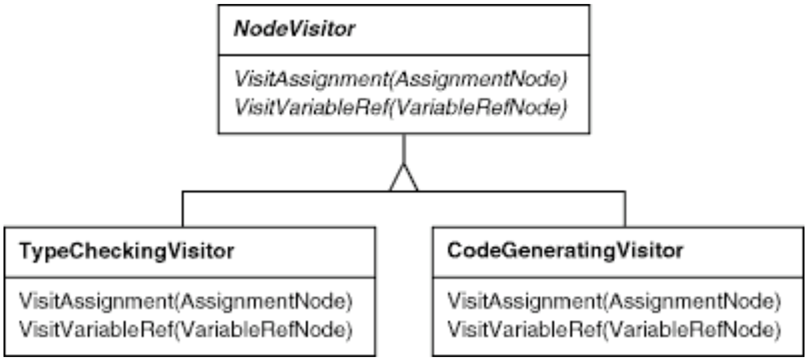
- Follows idea “objects are responsible for themselves”
- But many analyses will occlude the object’s main code
- Result is classes that are hard to maintain

Use a Visitor

- Alternatively, can define a separate **visitor** class
  - A visitor encapsulates the operations to be performed on an entire structure, e.g., all elements of a parse tree

- Allows operations to be separate from structure
  - But doesn't necessarily require putting all of the structure traversal code into each visitor/operation

Sample Visitor class



NodeVisitor

VisitAssignment(AssignmentNode)
VisitVariableRef(VariableRefNode)

TypeCheckingVisitor

VisitAssignment(AssignmentNode)
VisitVariableRef(VariableRefNode)

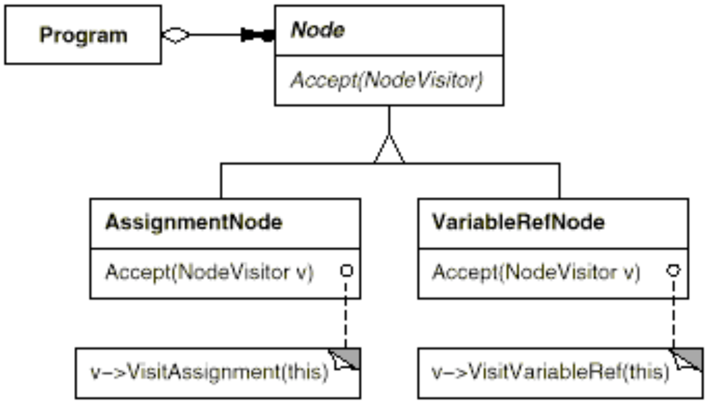
CodeGeneratingVisitor

VisitAssignment(AssignmentNode)
VisitVariableRef(VariableRefNode)

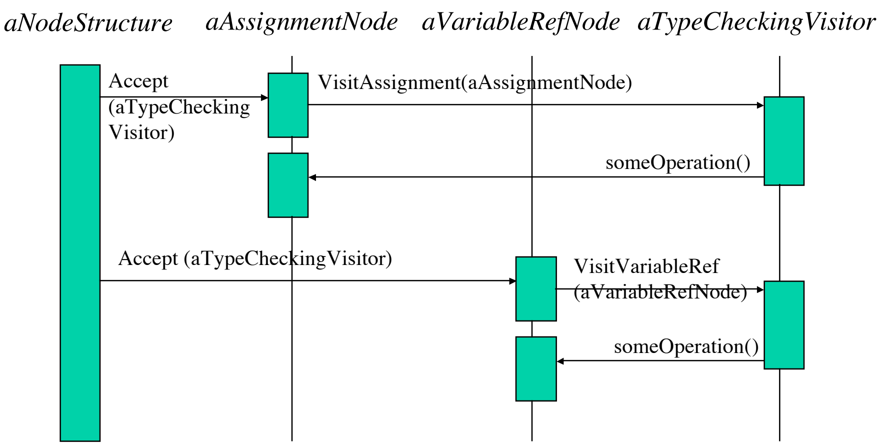
How to perform traversal?

- Now that we have a visitor class, how do we apply its analysis to the objects of interest?
  - Add **accept**(visitor) method to each structure class, that will invoke the given visitor on **this**
  - Builds on Java’s dynamic dispatch
  - Use an iteration algorithm (like an Iterator) to call accept() on each relevant object

Sample visited objects

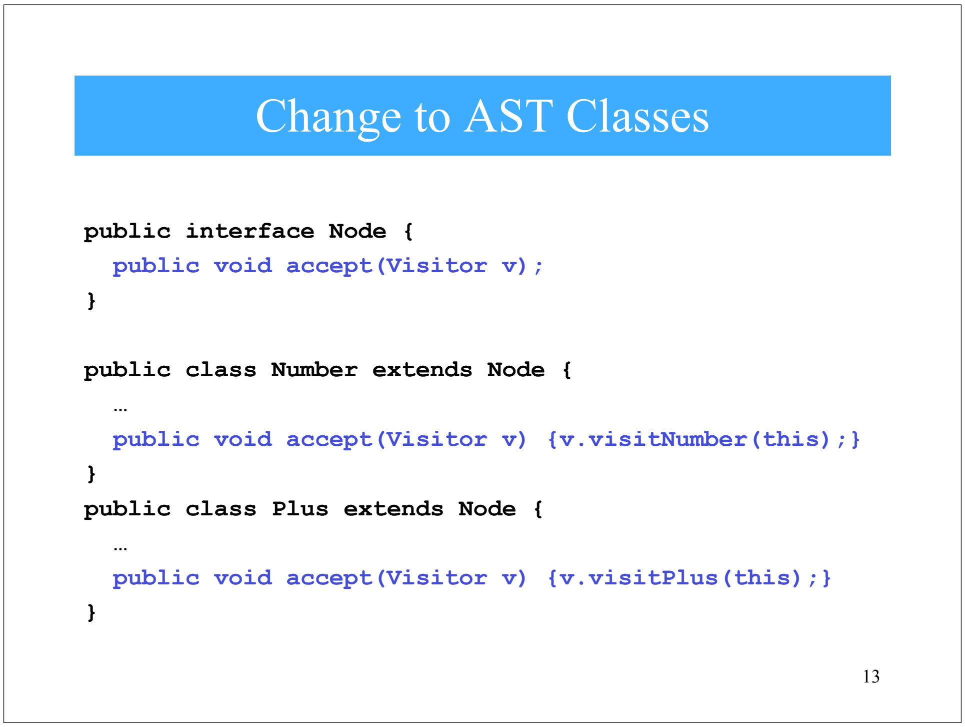


Vistor Interaction


aNodeStructure
aAssignmentNode
aVariableRefNode
aTypeCheckingVisitor
Accept (aTypeChecking Visitor)
VisitAssignment(aAssignmentNode)
someOperation()
Accept (aTypeCheckingVisitor)
VisitVariableRef (aVariableRefNode)
someOperation()

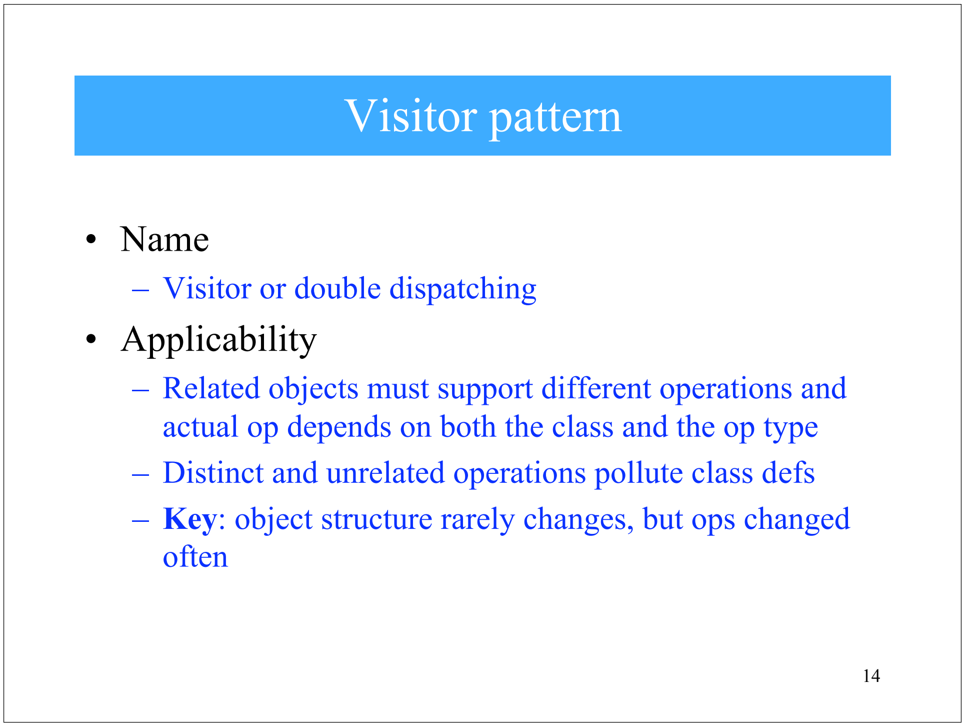
Sample Visitor Class

```
public interface Visitor {
  public void visitNumber(Number n);
  public void visitPlus(Plus p);
}

public class SumVisitor implements Visitor {
  int sum;
  public void visitNumber(Number n) { sum += n; }
  public void visitPlus(Plus p) {
    p.left.accept(this);
    p.right.accept(this);
}
```



Change to AST Classes

```
public interface Node {
  public void accept(Visitor v);
}

public class Number extends Node {
  …
  public void accept(Visitor v) {v.visitNumber(this);}
}
public class Plus extends Node {
  …
  public void accept(Visitor v) {v.visitPlus(this);}
}
```



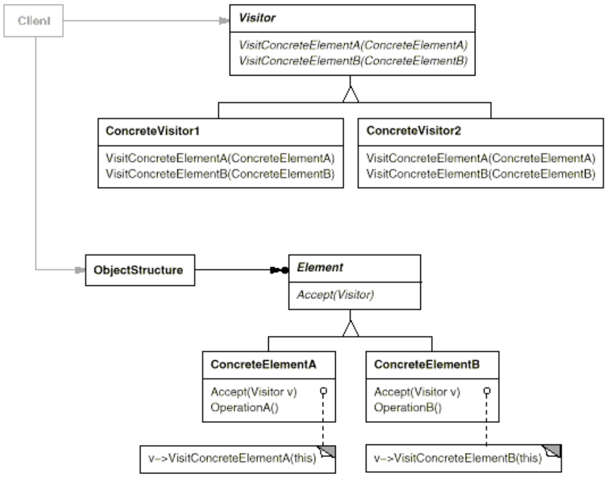
Visitor pattern

- Name
  - Visitor or double dispatching
- Applicability
  - Related objects must support different operations and actual op depends on both the class and the op type
  - Distinct and unrelated operations pollute class defs
  - **Key**: object structure rarely changes, but ops changed often

Visitor Pattern Structure

- Define two class hierarchies
  - One for object structure
    - AST in compiler, Menus and MenuItems in book example
  - One for each operation family, called visitors
    - One for typechecking, code generation, pretty printing in compiler
    - One for printing menus, figuring out the per/item average cost, etc.

Structure of Visitor Pattern



Client

Visitor
VisitConcreteElementA(ConcreteElementA)
VisitConcreteElementB(ConcreteElementB)

ConcreteVisitor1
VisitConcreteElementA(ConcreteElementA)
VisitConcreteElementB(ConcreteElementB)

ConcreteVisitor2
VisitConcreteElementA(ConcreteElementA)
VisitConcreteElementB(ConcreteElementB)

ObjectStructure

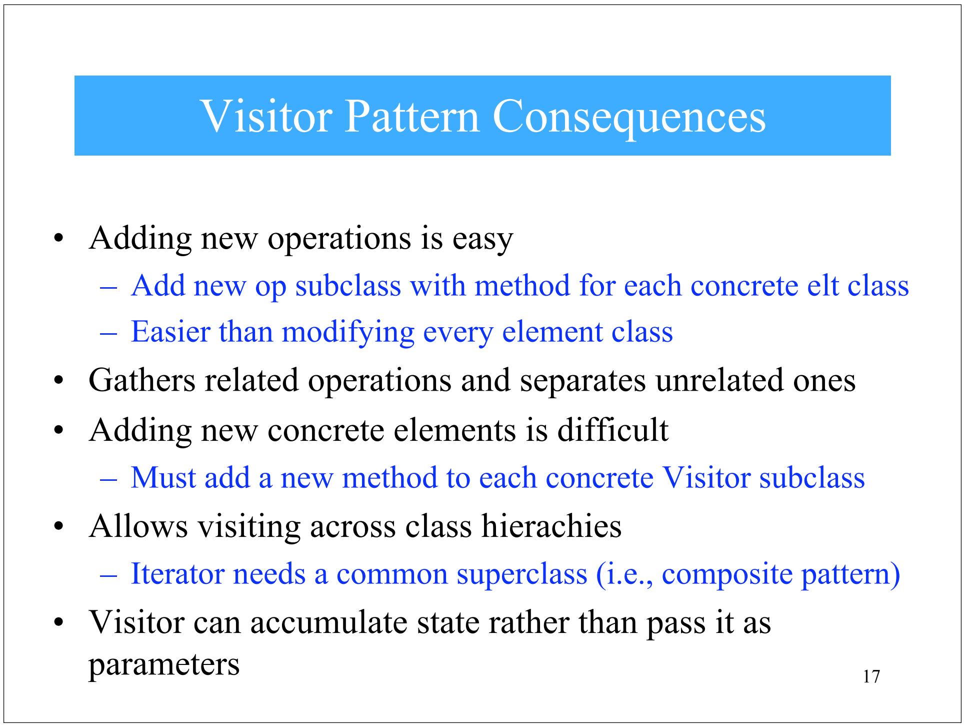
Element
Accept(Visitor)

ConcreteElementA
Accept(Visitor v)
OperationA()

ConcreteElementB
Accept(Visitor v)
OperationB()

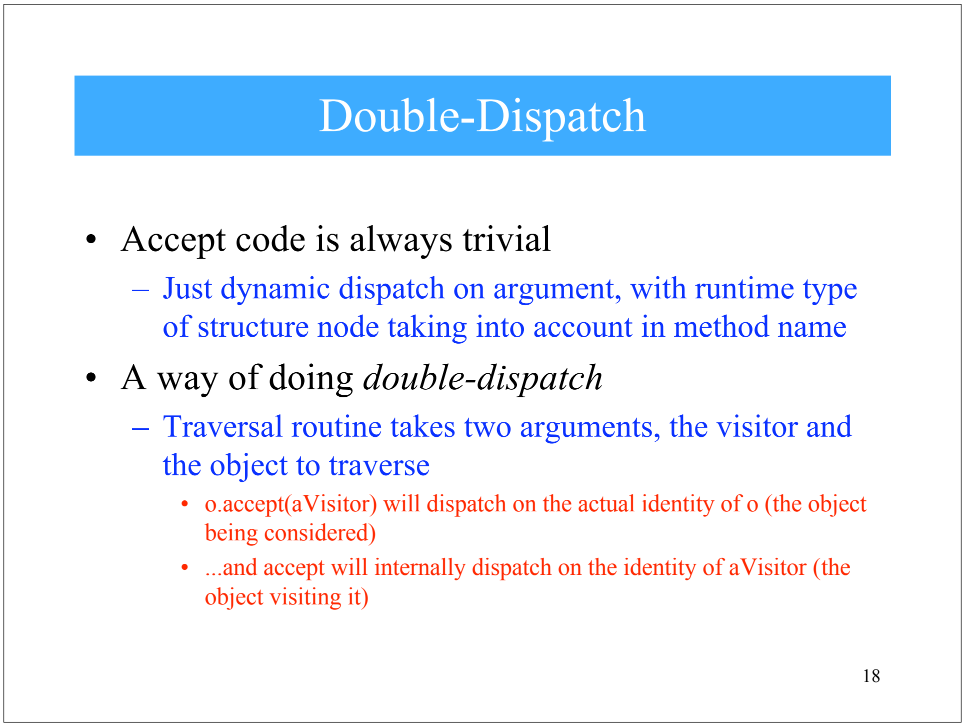
v->VisitConcreteElementA(this)

v->VisitConcreteElementB(this)



Visitor Pattern Consequences

- Adding new operations is easy
  - Add new op subclass with method for each concrete elt class
  - Easier than modifying every element class
- Gathers related operations and separates unrelated ones
- Adding new concrete elements is difficult
  - Must add a new method to each concrete Visitor subclass
- Allows visiting across class hierachies
  - Iterator needs a common superclass (i.e., composite pattern)
- Visitor can accumulate state rather than pass it as parameters



Double-Dispatch

- Accept code is always trivial
  - Just dynamic dispatch on argument, with runtime type of structure node taking into account in method name
- A way of doing *double-dispatch*
  - Traversal routine takes two arguments, the visitor and the object to traverse
    - o.accept(aVisitor) will dispatch on the actual identity of o (the object being considered)
    - ...and accept will internally dispatch on the identity of aVisitor (the object visiting it)

Using Overloading in a Visitor

- You can name all of the visitXXX(XXX x) methods just visit(XXX x)
  - Calls to Visit (AssignmentNode n) and Visit(VariableRefNode n) distinguished by compile-time overload resolution

Visitors Can Forward Common Behavior

- Useful for composites
  - If subclasses of a particular object all treated the same
  - Can have visit(SubClass) call visit(SuperClass)
- For example
  - visit(BinaryPlusOperatorNode) can just forward call to superclass visit(BinaryOperatorNode)

State in a Visitor Pattern

- A visitor can contain state
  - E.g., the results of typechecking the program so far

```
class TypeCheckingVisitor extends Visitor {
  private TypeMap map;
  void visit(VariableDefNode n) { …
    map.add(n,t)
  … }
}
```

- Or visitors pass around a separate state object
  - Impacts the type of the Visitor superclass

Implementing Traversal

- Who is responsible for traversing object structure?
- Plausible answers:
  - Visitor
    - But, must replicate traversal code in each concrete visitor
  - Object structure
    - Define operation that performs traversal while applying visitor object to each component
  - Iterator
    - Iterator sends message to visitor with current element as arg

Traversals

- It’s sometimes preferable to try to keep traversal separate from the Visitor
  - E.g., use an Iterator
  - Thus traversal and analysis can evolve independently
- But can also do it within node or visitor class. Several solutions here:
  - **acceptAndTraverse** methods
    - traverse from within accept()
  - Separating processing from traversal
    - Visit/process methods
  - Traversal visitors applying an operational visitor

Accept and Traverse Example

- Class BinaryPlusOperatorNode {

```
    void accept(Visitor v) {
            v.visit(this);
            lhs.accept(v);
            rhs.accept(v);
            }
    …}
```

acceptAndTraverse Methods

- Accept method could be responsible for traversing children
  - Assumes all visitors have same traversal pattern
    - E.g., visit all nodes in pre-order traversal
  - Could provide previsit and postvisit methods to allow for more complicated traversal patterns
    - Still visit every node
    - Can't do out of order traversal
    - In-order traversal requires inVisit method

Visitor/Process Methods

- Can have two parallel sets of methods in visitors
  - Visit() methods
  - Process() methods
- How it works: the visit() method on a node:
  - Calls process() method of visitor, passing node as an argument
  - Calls accept() on all children of the node (passing the visitor as an argument)
- Allows finer-grained subtyping of Visitor classes that include traversal
  - Subclass a visitor, and just change the process method

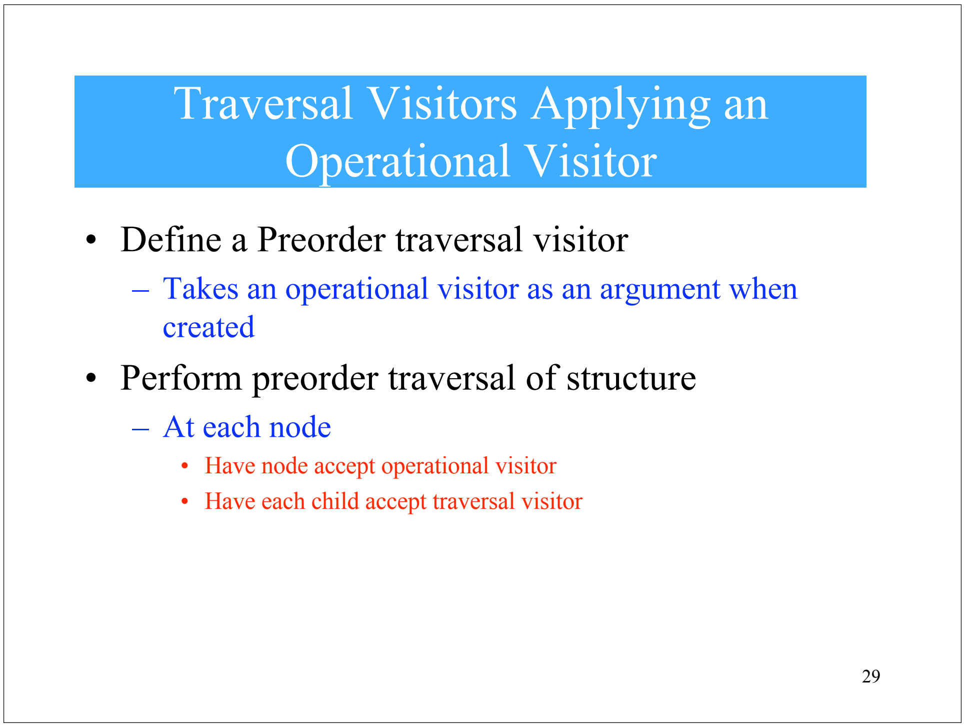
Preorder Visitor

- Class PreorderVisitor {

```
void visit(BinaryPlusOperatorNode n) {
        process(n);
        n.lhs.accept(this);
        n.rhs.accept(this);
        }
…}
```

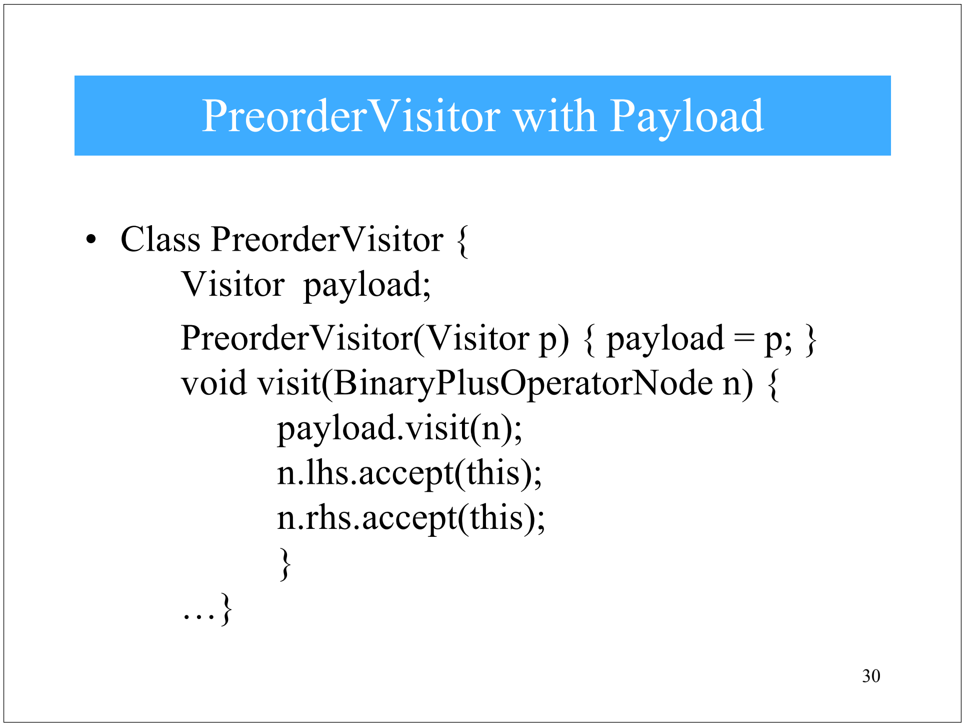
Visit/Process, Continued

- Can define a PreorderVisitor
  - Extend it, and just redefine process method
    - Except for the few cases where something other than preorder traversal is required
- Can define other traversal visitors as well
  - E.g., PostOrderVisitor



Traversal Visitors Applying an Operational Visitor

- Define a Preorder traversal visitor
  - Takes an operational visitor as an argument when created
- Perform preorder traversal of structure
  - At each node
    - Have node accept operational visitor
    - Have each child accept traversal visitor



PreorderVisitor with Payload

- Class PreorderVisitor {

```
      Visitor  payload;
      PreorderVisitor(Visitor p) { payload = p; }
      void visit(BinaryPlusOperatorNode n) {
              payload.visit(n);
              n.lhs.accept(this);
              n.rhs.accept(this);
              }
      …}
```